WELL WATER QUALITY AND TREATMENT IN NEW BRUNSWICK

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PREFACE

This report on Well Water Quality and Treatment in New Brunswick is prepared for public information and assistance as part of the Municipal Affairs and Environment's effort in promoting efficient development and wise use of our water resources to support the social and economic development priority of the Province. By publishing this report, we hope to clarify problems and their remedial measures in New Brunswick. We stress the importance of the understanding of the basic water quality problems and available treatment technologies so that sound decisions can be made.

During the preparation of the report, we have received many helpful comments, suggestions, and literature from various treatment firms, equipment suppliers, and manufacturers. Recognizing the complexity of the water quality problems and the changing nature of water treatment technologies, the Department of Municipal Affairs and Environment does not undertake to make, nor does it assume, any responsibility for an evaluation of a particular product. It is the responsibility of the individual to make his/her own evaluation and selection.

This report was adapted from a similar report completed by the Nova Scotia Department of the Environment in 1986. The Nova Scotian report was written by Messrs. Norman McLeod and Douglas Farrell under the direction of Dr. C.L. Lin, Chief of Water Resources Planning in the Department. Appreciation is extended to the Nova Scotia Department of the Environment for allowing us to adapt their report to prepare the following.

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1.0 INTRODUCTION

The importance of water in today's society cannot be overemphasized. Water is used for drinking, bathing, household, and industrial cleaning and for carrying away and diluting waste. Today, each member of the average Canadian family uses 140 to 320 litres (30 to 70 gallons) of water each day. Each trip to the bathroom uses 14 to 23 litres (3 to 5 gallons) of water. Altogether, some 4,546 litres (1,000 gallons) per person per day are needed for manufacturing, industrial, municipal, rural, agriculutral, and mining uses.

This booklet discusses the background of typical well water problems in New Brunswick and presents various remedial measures. Each section of this report includes the cause(s) of the problem, the adverse effects of the problem (on water taste, health, etc.), treatment alternatives, cost estimates of treatment methods, and a suggestion where to get the water analyzed for that particular problem. The treatment methods presented are generally applicable to domestic water systems. For the sake of completeness, some of the more unusual systems are mentioned. A summary of problems and treatments is presented in Table 2.

In New Brunswick approximately 66 percent (Hess, 1986) of the population utilizes groundwater sources for drinking. To be useful, water must be available in quantity and quality, at the time and location suitable for the need. A mean annual precipitation of approximately 1120 mm (44 inches) ensures that there is sufficient recharge to groundwater to prevent widespread

droughts from occurring. The actual quantity of water available for withdrawal depends on local hydrogeological conditions and the effectiveness of the well.

Wells in this Province are either shallow dug wells in the unconsolidated overburden or deeper wells drilled into the bedrock. Overburden is predominantly low water-yield glacial till. Because of its low yield, dug wells are usually constructed of 90 cm (3 ft.) diameter crocks with large amounts of storage. Drilled well yields depend on the type of bedrock (Figure 1), the type of overburden, the depth of the well, and the number of fractures or cracks encountered in the rock while drilling. In areas where the overburden consists of sand and gravel saturated with water, construction of screened drilled wells or well points often results in high yield wells with good quality water.

In New Brunswick, bedrock is generally close to the surface and, commonly, is exposed. The scarcity of overburden often reduces the availability of the natural filtering mechanism of the soil. Once this penetrating water is in the bedrock, there is relatively little filtering action. Also, the relatively large amount of precipitation in the province ensures that the water table is fairly close to the surface.

Because of the close proximity of groundwater to the surface, potentially polluting activities can seldom be situated so they will not interact with the water table. Therefore,

groundwater is susceptible to contamination if proper steps are not taken. The efforts required to protect groundwater are usually more effective and cheaper than water treatment methods added later to solve a problem. For example, a high nitrate-bacteria problem is most easily dealt with by removing potential sources of pollution, such as manure piles, from the area of the well.

Despite the problems that can occur with groundwater, well water in the province is generally of good quality. However, there are exceptions. In certain areas of New Brunswick, mainly due to geologic conditions or areas of culturally-caused pollution, there exists poor quality water requiring treatment. Poor quality water is generally defined as that water which exceeds the Guidelines for Canadian Drinking Water Quality 1978 (Table 1). With these waters, some form of water treatment may be required.

Before treatment is decided upon, the feasibility of all possible options should carefully assessed. Alternatives to treatment might include the following;

1) A new Well
2) A collective system with a neighbour(s)
3) Hook-up to Municipal System
4) Rain water collection for direct use or mixing.

Carefull analysis both of the water quality problem and the feasible solutions will be required to ensure that the most suitable option is chosen.

Water treatment needs to be approached in a systematic way in order to ensure its cost-effectiveness. The first step is to properly define the problem or treatment need. Usually this means that a number of water samples need to be taken. These should be representative as is possible; that is they should be typical of the problem. If large variation is seen in the chemical quality then more samples should be taken to ensure that this variation is well understood.

As the sample(s) that you take will influence the kinds of treatment finally decided upon and on the final cost, it is very important that this work be done as objectively as possible by a reliable laboratory.

Some problems can be solved simply by performing adequate maintenance either on the well, the pumping system or the septic tank. For example shock chlorination every six months may be the most cost effective approach to controlling a low level iron problem. Adequate access will be needed to make this easy to perform.

Turbidity problems may have a variety of causes which might be caused by the water system. Common easy to solve problems include a blocked vent at the wellhead, or pump suctions that are set too deeply in the well. You must be certain that the water system is not causing or contributing to the problem before you choose treatment. Other problems can be solved by installing more casing or by sealing the existing casing or draining the wellhead area.

There are times and circumstances when treatment even when suitable, may not be appropriate. There are no simple rules that can be followed, however typical circumstances when treatment would not be the best solution are;

1) When it can't be economically done for the quantity of water required (eg. Salt).

2) When non contaminated alternative sources are cost competitive (see options above).

3) When problem can easily be solved by other means, perhaps by removing the source of the problem.

4) When the treatment method is not technically feasible for the domestic water supply situation in general or for a specific water quality type (eg. sulphate, pesticides).

The initial cost of treatment and the cost of maintenance is directly related to the amount of water which is treated. It may be essential with some forms of treatment to reduce the amount treated to that which is required. Drinking water standards are usually the most stringent. Most households only need 20 to 40 litres of water solely for drinking purposes. Some mixing after treatment will improve the taste of the finished product and give the required treatment to a larger quantity of water and so is worthy of consideration. This is particularly true of reverse osmosis or distillation which remove almost all the mineral content.

When asking for quotations for water treatment equipment, be sure that estimates of operating and maintenance costs are included. This would normally include the cost of replacement resins, chemicals, replacement cartridges and electrical power. Under adverse circumstances these costs may become prohibitive. Suppliers should be able to tell you typical costs for their equipment for the most common applications.

Water is an effective solvent and tends to pick up various chemicals from natural materials. Because of its slow movement and greater travel through earth materials, groundwater or well water generally has a higher mineral content than surface water. Due to the filtering action of the soil, well water usually has a lower bacterial population and is clearer and cleaner than surface water.

TABLE 1

ABBREVIATED GUIDELINES FOR CANADIAN DRINKING WATER QUALITY 1978

Substance or Parameter	Maximum Acceptable Level, mg/L	Objective, mg/L
Bacteria	*(1) 10 or less total coliforms per 100 ml of water. (2) no coliforms in not more than 10% of samples in 30 day period. (3) no coliforms present in more than 2 consecutive samples from the same site. (4) no fecal coliforms.	
Colour (True colour units)	15 TCU	<15 TCU
Odour	—	inoffensive
Taste	—	inoffensive
Turbidity (nephelometric turbidity units)	5 NTU	<1 NTU
pH	6.5 - 8.5 pH units	
Arsenic	*0.05	$\underline{<}$0.005
Chloride	*250	$\underline{<}$250
Copper	1.0	<1.0
Fluoride	*1.5	1.0
Hardness	500	80 - 100
Hydrogen Sulfide	*0.05	<0.05
Iron	0.3	<0.05
Lead	*0.05	$\underline{<}$0.001
Manganese	0.05	$\underline{<}$0.01
Nitrate (as N)	*10.0	$\underline{<}$0.001
Sulphate	*500	$\underline{<}$150
Total Dissolved Solids	500	
Uranium	*0.02	$\underline{<}$0.001
Zinc	5.0	$\underline{<}$5.0

*Based on health considerations.

Water quality problems can be divided into manmade and natural problems. The naturally occurring problems may include excessive concentrations of iron, manganese, sulphate, chloride, arsenic, uranium, calcium, and magnesium in the well water. The manmade problems include nitrate and bacteria from septic fields and fertilizers; salt from road de-icing operations; hydrocarbons from leaking gas and oil tanks; methane, sulphates, and chlorides from landfill sites; and pesticides from home, farm, or forestry usage (Shawiningan Engineering Ltd., 1980). Some of these chemicals, such as arsenic, pose a potential health hazard. Others, such as iron, may merely be aesthetically displeasing; i.e. they may stain laundry or impart a bad taste to the water. Most of these water quality problems can be reduced by various physical and chemical means, in addition to other alternatives. The decision on the course of action to be taken depends on the type of problem, technical feasibility, alternatives available, and, of course, the cost. Table 2 presents a list of common domestic water quality problems, their causes and possible corrective measures.

TABLE 2
COMMON DOMESTIC WATER QUALITY PROBLEMS AND TREATMENT

Problem	Probable Cause	Corrective Measures
Mineral scale buildup in kettles, heaters, and plumbing. Soap scum, excess soap consumption, dingy laundry, bathtub ring.	Hardness (Hard water)	Water softeners Phosphate feed
Red stains on laundry Metallic taste in water Red colour to water	Iron	Water softeners Chemical oxidation and filtration Greensand filters
Black stains Red-black water Metallic Taste	Manganese	Water softeners Iron filters
Red-brown slime Red filaments Reduced well yield	Iron Bacteria	"Shot" or "Shock" chlorination Chlorination filtration units
Gastro-intestinal disease	Bacteria or virus	Disinfection: - chlorine - ozone - iodination - ultraviolet
Corrosive Water	Acid Water (low pH)	Tank type neutralizers Chemical feed of an alkaline material Sodium silicate filters Well rehabilitation
Salty taste, corrosive	Chloride	Reverse osmosis Deionization Distillation Eliminate source Well rehabilitation

TABLE 2 (contd.)
COMMON DOMESTIC WATER QUALITY PROBLEMS AND TREATMENT

Problem	Probable Cause	Corrective Measures
Bitter taste, laxative effect	Sulfate	Dealkalization Distillation
Blue hue in infants	Nitrate	Deionization Distillation Freezing/thawing Reverse osmosis Case well to deeper zone
Rotten egg smell which disappears if water is left standing	Hydrogen Sulfide (H_2S)	Activated carbon filters Oxidation - filtration Check well venting
Tastes and Odours	Dissolved Organics	Activated carbon Aeration
Cloudy or turbid water	Suspended Particles (silt, clay)	Alum treatment Gravity Sedimentation
Neural problems, skin lesions, etc.	Arsenic	Arsenic Filter Distillation Dug well construction
Uranium and/or Radioactivity	Uranium, Radon	Construction of a dug well Distillation Reverse osmosis Vent well and house
Hypertension	Sodium	Well Rehabilitation (road salt) Install a "non-softened" tap for drinking Reverse osmosis Distillation
Gasoline-type odour	Gasoline Fuel Oil	Charcoal Filters Reverse osmosis Aeration
Clear Tea-like colour	Humic Acids	Charcoal Filters

2.0 BACTERIAL CONTAMINATION

As defined in the Canadian Drinking Water Guidelines, bacterial contamination becomes of concern when there are more than 10 total coliform bacteria per 100 ml of water (for more details see Table 1). Coliform bacteria are used as an indicator of contamination. They are not harmful but may indicate the presence of other disease-causing bacteria or viruses.

As Table 3 illustrates, bacterial contamination of water from sources such as septic fields or manure piles can cause a wide range of infections and disease. However, the filtration capability of soil and rock and oxygen-free conditions that exist underground all act to reduce the number of bacteria that move through the ground with groundwater. Accordingly, groundwater is generally a safer drinking water source than surface waters with respect to pathogenic or disease-causing organisms.

The distance that bacteria and virus-contaminated water can travel in the ground depends on the type of soil or bedrock, the type of water, and the type of bacteria. For instance, bacteria and viruses may travel one hundred metres in fractured bedrock while the same bacteria may be completely filtered out in thirty metres of saturated porous sand (Crane and Moore, 1984).

TABLE 3

PATHOGENIC ORGANISMS FOUND IN WATER
AND THE POSSIBLE RESULTING INFECTION/DISEASE 1,2

Bacteria/Protozoa	Possible Infection/Disease
Escherichia coli (E. coli)	Urinary tract infections, diarrhea in some individuals
Pseudomonas aeruginosa	Otitis externa ("swimmers ear" infection)
Salmonella, various types	effects range in severity from typhoid fever, to the common acute intestinal upsets formally known as "ptomaine poisoning"
Klebsiella pneumoniae	may cause a highly fatal type of pneumonia which accounts for 3% of bacteria pneumonia
Bacillus anthracis	causes anthrax in animals which can then be transmitted to humans
Clostridium tetani	if spores are introduced into deep wounds during bathing can cause tetanus ("lockjaw")
Vibrio chloreae	cholera, organism may persist for weeks in either very clean or very turbid water
Shigella, various types	acute diarrhea
Yersinia tularensis	gastroenteritis
Francisella tularensis	tularemia, spread via drinking water contaminated by wild animals in rural areas
Entamoeba histolytica	amoebic dysentery - requires fine filtration of water
Glardia lamblia	recurring diarrhea - requires fine filtration of water

1. Ontario Ministry of the Environment, 1981, pp. 107-117.
2. Lehr et al., 1980, pp. 134-137.

The major causes of bacterial contamination in domestic wells are related to poor design, siting, or construction of on-site services. For information on well construction, see the Municipal Affairs and Environment's booklet "Construction and Testing Procedures for Drilled Water Wells."

Water supplies derived from surface water and rainwater almost always require disinfection. Prior to the implementation of any disinfection procedure described in this publication, all reasonable measures to eliminate the problem at the source should be carried out (e.g. well rehabilitation, removal of waste piles, diversion of drainage). Care should be taken in digging diversion ditches that they don't aggrevate the contamination problems by opening up pathways to the contaminated well.

In the cases where the above procedures are ineffective or where surface water is the source of supply, disinfection and/or filtration may be required before the water is drinkable. Disinfection involves killing the microorganisms by various means.

2.1 Chlorination

Chlorination is the most common method of disinfection. There are two types of chlorination: "shock" and "shot" chlorination and continuous chlorination.

Shot chlorination involves the manual addition of a quantity of chlorine to a well (i.e. a bottle or two of Javex) to

eliminate a temporary bacterial contamination problem. Shot chlorination is described further in Appendix C.

Continuous chlorination involves the continuous addition of a small quantity of chlorine to the water system. It is used to disinfect a source of water, such as lake water, which may at any time contain disease-causing bacteria.

2.1.1 Types of Chlorinators

There are 3 major types of chlorinator units used for the continuous addition of chlorine:

1) The "pump type," positive displacement of "P.D." feeder is an electrically powered unit that operates by alternately expanding and compressing a rubber device (like a plunger) or by moving a piston (like a syringe). The equipment is adjustable during operation and is especially desirable where water pressure is low or fluctuating (Figures 2 and 3).

2) Eductor-type chlorinators use the natural vacuum created by the flow of water in a pipe to draw the chlorine solution from the disinfectant reservoir. The two most common types of eductor feeders are aspirator and suction feeders.

   Aspirator feeders utilize the vacuum created by the water flowing perpendicular to a nozzle. The vacuum draws the chlorine solution from a container

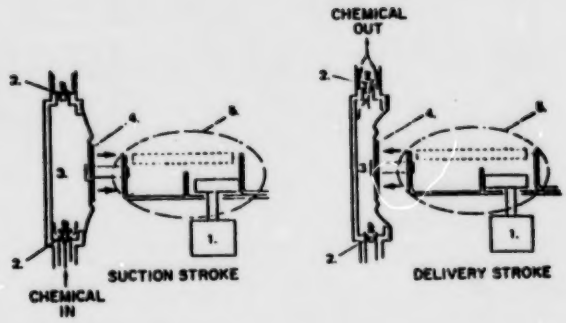

Figure 2. A common type of positive-displacement feeder. As the diaphragm (4) is pulled back, the volume of the chamber (3) is increased. A partial vacuum is formed, pulling the liquid through the lower check valve (2) and into the chamber. The diaphragm then moves forward, the lower check valve closes, and the liquid is forced through the upper check valve (2) to the point of injection.*

*Lehr et al., 1980, p. 142

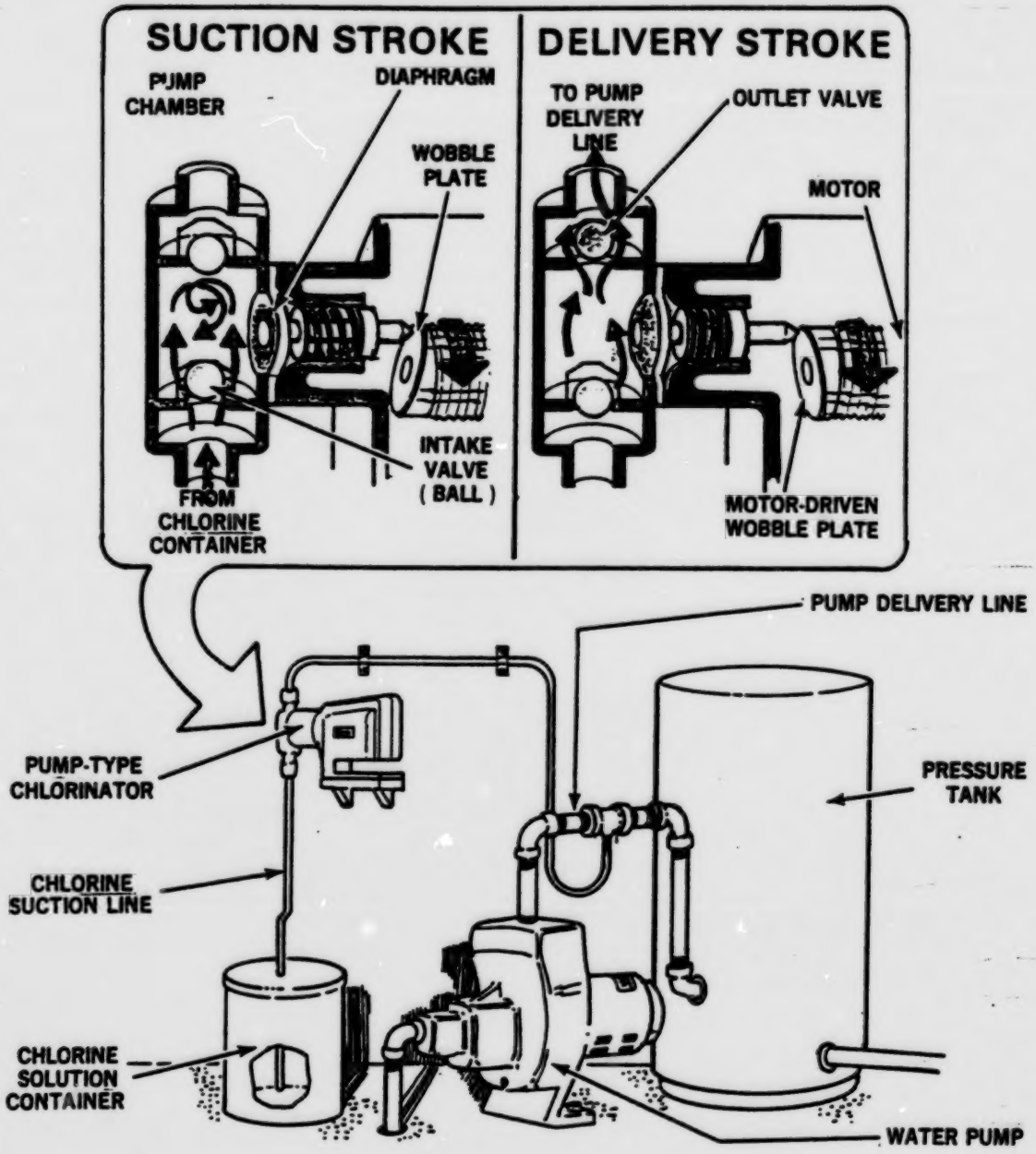

FIGURE 3: Pump-type diaphragm chlorinator driven by an electric motor. Chlorinator operates continually while water pump is in operation. It is positive acting - delivering a fixed amount of chlorine solution with each discharge stroke.*

*Henderson, 1973, p. 35.

into the chlorinator unit where it is mixed with water passing through the unit. The solution is then injected into the water system (Figure 4).

Suction type feeders have a single line that runs from the chlorine solution, through the chlorinator unit, and connects to the suction side of the pump. The solution is pulled from the container by suction created by the pump.

3) Tablet hypochlorinators (Figures 5 and 6) consist of a special pot feeder containing calcium hypochlorite tablets. Small jets of feedwater are injected into the lower portion of the hypochlorite bed. Dissolution provides a continuous source of fresh hypochlorite solution. The unit does not require electricity and can operate where water pressure is low.

The three types of units mentioned, P.D., eductor, and tablet hypochlorinators, are all quite effective and are roughly the same cost (approximately $600*). Choice of a suitable unit is a matter of personal preference as to the exactness of dosage, degree of maintenance, pressure, and rate of water use.

*The estimated costs are based on 1987 prices.

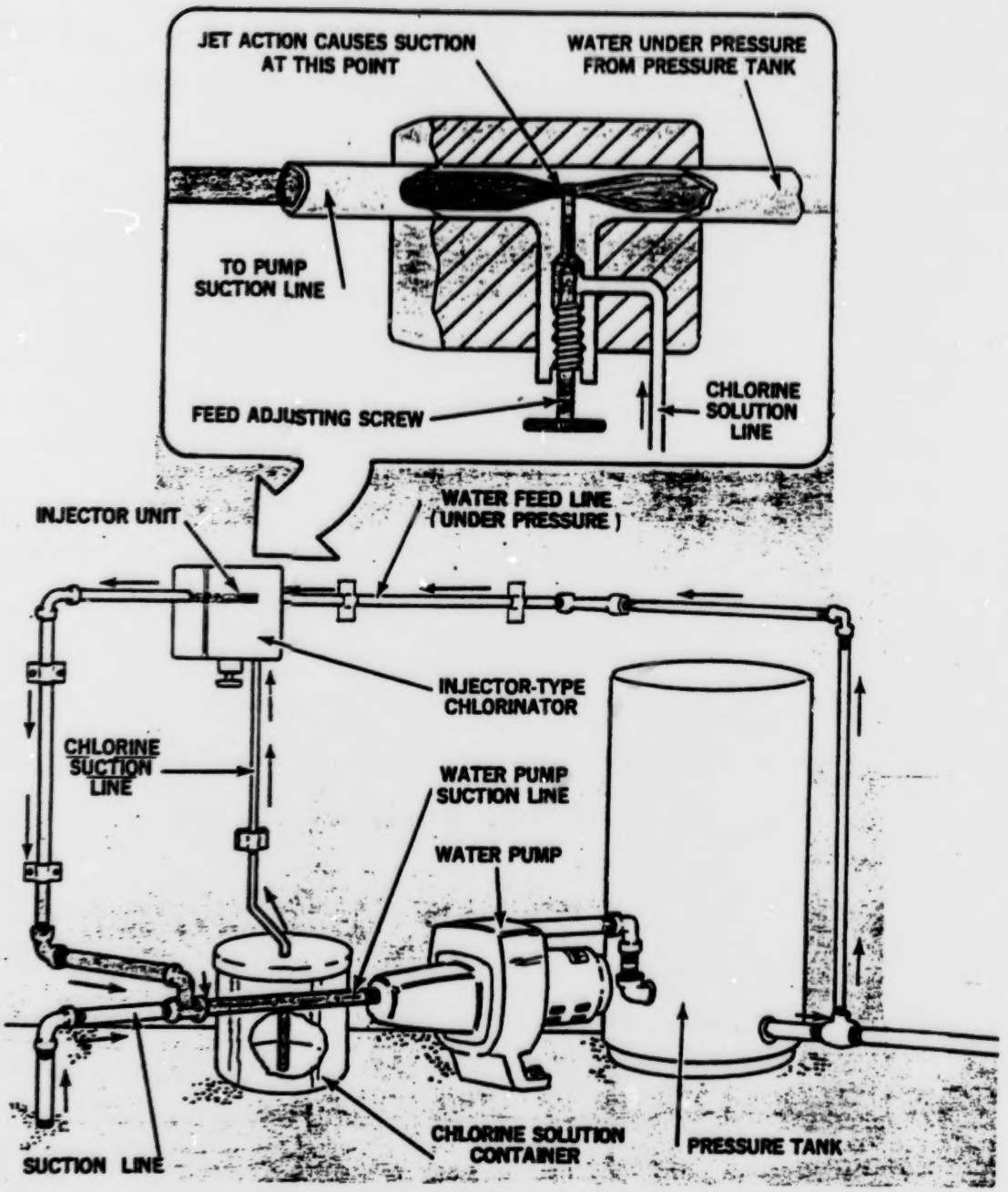

FIGURE 4: Injector-type chlorinator. Chlorine solution is drawn by jet (injector) action into the water supply system.*

* Henderson, 1973, p. 36.

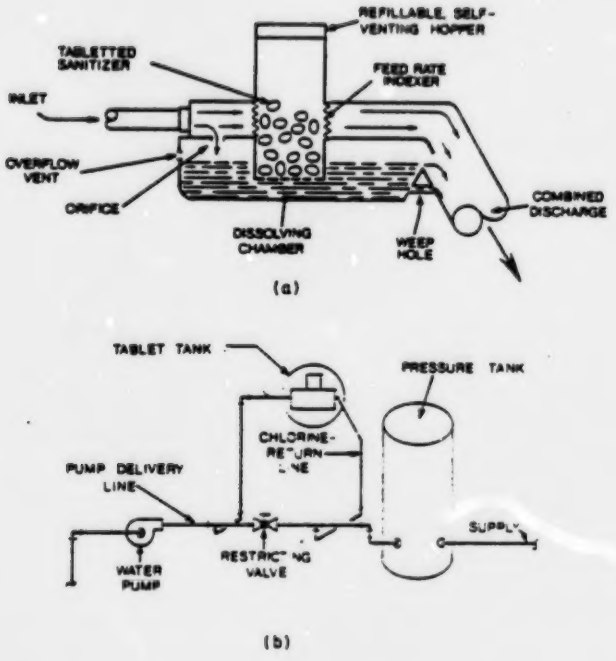

FIGURE 5. Tablet hypochlorinator.*

*Lehr et al., 1980, p. 146

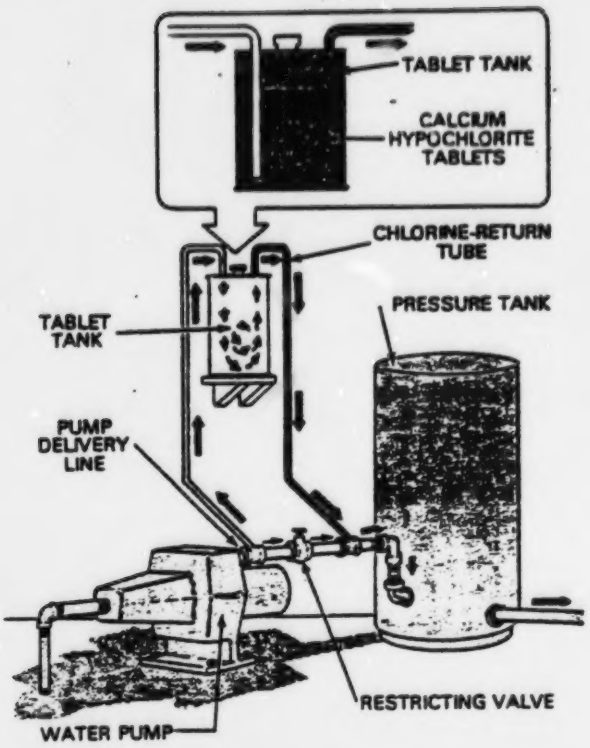

FIGURE 6. A tablet-type chlorinator bypasses water through a tank containing calcium hypochlorite tablets. The water dissolves a portion of the tablets and is returned to the pump delivery line ahead of the pressure tank.*

Henderson, 1973, p. 37.

2.1.2 Advantages and Disadvantages of Chlorination

On the positive side, chlorine is a highly effective disinfecting agent. It is relatively safe and inexpensive. Chlorine is also effective in the oxidation of iron and manganese. This allows the iron and manganese to be removed by filtration at a later stage (Section 4.2.1).

On the negative side, chlorine may combine with certain organic particles in the water to form suspected cancer causing chemicals (Lehr et al., 1980, p. 148). Insufficient quantities of chlorine may allow the survival of some disease-causing bacteria, whereas too much chlorine may impart a bad taste and odour to the water. This means that care must be taken in adjustment of the feeders. Cloudy water may reduce the effectiveness of chlorinators. Variation in water quality may affect the degree of protection given by a specific pre-set dosage of chlorine. Feeder units require varying degrees of maintenance depending upon the type.

2.2 Ozonation

Ozonation occurs when ozone gas (O_3) is drawn into the water to kill bacteria. Ozone is quite a popular disinfectant. However, it is not used as extensively in North America as in Europe. Local "spring water" distributors favour ozone because it leaves no taste or odour in the water. Ozone is actually more effective against bacteria and viruses than is chlorine. It also may reduce iron, manganese, and lead content of the water by oxidation and is not affected by pH, temperature, or ammonia.

Ozonation must occur at the point of use. The disadvantages of ozonation include:

1. Higher operating costs than chlorination.
2. No lingering bacteria-killing ability as there is with the use of chlorine.
3. Production of many by-products which have undetermined effects on human health.

These units are available in New Brunswick from distributors at an average cost of about $2,500 for a unit capable of treating a residential supply.

2.3 Iodination

Iodination is another treatment method available for disinfection. Iodine has been used as an antiseptic and a biocide for over 100 years. Disinfection is achieved by adding a controlled amount of saturated iodine solution to water. The iodine can be added by means of a chemical feed pump or an iodination cartridge. The latter requires no electricity and may last five years for a family of four. Generally, a cartridge filter is required before iodination to protect the unit from sediments.

Approximately 1 mg/L of iodine is added to the water. Use of iodine gives the water a residual bacteriocidal activity that will kill off any bacteria in the plumbing system. Apparently iodine does not give the water any objectionable taste or odour at proper treatment levels. Iodine is effective in the pH range 5 to 9.

Water with a high organic content may use too much iodine thus preventing the use of iodine for disinfection. Persons with thyroid conditions who should not consume iodine can have a charcoal filter installed to remove the iodine before consumption.

2.4 Ultraviolet Irradiation

Ultraviolet water-disinfection systems use the same killing action on bacteria as sunlight. The germicidal activity depends on the intensity of the lamp and the length of exposure. The system consists of one or more ultraviolet lamps in a quartz sleeve. Water is directed past the lamp in a relatively thin layer so that all of the bacteria in the water are exposed.

It is important that the water is clear so that none of the bacteria escape irradiation by being in the shadow of particles. Accordingly, a filter is usually installed before the lamp to remove dirt, rust, and hydrogen sulfide.

The systems are automatic, use no chemicals, and produce no by-products that cause tastes or odours. Unlike chlorination systems, the ultraviolet lamps have no residual germicidal acitivity. Therefore, the plumbing system should be periodically cleaned and disinfected. It consumes 40 - 90 watts of power. The ultraviolet system sells for $300 - $700. Replacement cells cost $50 - $170.

2.5 Bacterial Monitoring

Testing for bacteria should only be done in a laboratory with microbiology facilities. There is no simple reliable test kit as there is for many other problems. In New Brunswick, the coliform group of microorganisms are the commonly used bacteriological indicators of water quality. Fecal coliforms characteristically occur in the intestines and feces of warm-blooded animals. The presence of these organisms indicates the potential presence of disease-causing bacteria at the source. Any water supply that is being continuously disinfected should be monitored to ensure that all bacteria are being killed. The New Brunswick Department of Health and Community Services will perform free tests on an individual water supply.

A typical test for these organisms involves growing them in a particular medium, in a number of test tubes or petri plates. The production of gas or growth of colonies is monitored to determine the presence and concentration of organisms.

The Guidelines for Canadian Drinking Water Quality 1978 (Table 1) state that:

1. No sample should contain more than 10 total coliform organisms per 100 millilitres.
2. Not more than 10 percent of the samples taken in a 30 day period should show the presence of coliform organisms.
3. Not more than 2 consecutive samples from the same site should show the presence of coliform organisms.
4. None of the coliforms detected should be fecal coliforms.

The bacterial rating of drinking water is illustrated in Table 4. Note that the information on Table 4 is from Ontario. Interpretation of the bacterial water quality may vary slightly in New Brunswick.

TABLE 4
INTERPRETATION OF COLIFORM COUNTS*

Coliform Bacteria per 100 mL		Interpretation
Total	Fecal	
160	60	Unsafe for drinking. This water is contaminated and should not be used for drinking under any circumstances. Do not attempt to apply these standards and interpretations to surface waters used for swimming.
10-160	1-60	Unsafe for drinking. Pollution source may be some distance from the water source, or diluted with large volumes of pure water, or the sample may not have been received within 48 hours of being taken. Samples older than 48 hours cannot provide reliable results.
10-160	0	Unsafe for drinking. Contamination is not likely to be of sewage origin unless far removed from the water source or unless there has been a delay in receipt of sample. Common with new wells before disinfection and shallow dug wells which are not properly sealed.
1-9	0	Doubtful for a single sample, but safe for drinking if condition remains stable and supply is protected and located at least 100 ft. from any source of human or animal wastes. Repeat samples may not show exactly the same results because bacteria are not distributed uniformly in water, contamination tends to enter intermittently, and numbers can change during sample transit time. Frequent sampling recommended.
0	0	Safe for drinking.

*Adapted from the Ontario Ministry of the Environment, 1980.

3.0 HARD WATER

Hardness in water is commonly defined as the inability of the water to form soap lather. Actual hardness is determined by the calcium and magnesium content of the water as $CaCO_3$. These elements dissolve as water flows through certain soil and rock units which contain limestone, dolomite, and gypsum.

"Hard" water leads to technical and economic problems. It can cause scale to form on kettles and boilers, prevent soap from lathering and give a dingy appearance to laundry. High concentrations are not known to pose a health hazard. In fact, hard water may have a beneficial effect.

In Canada, acceptable hardness can range as high as 80 and 100 milligrams per litre of water. Many treatment companies refer to the older, English units of measurements such as grains per gallon. Five to six grains per gallon (gpg) is considered acceptable and is equivalent to 80 to 100 milligrams per litre (mg/L). Grains per gallon can be converted to milligrams per litre by multiplying the gpg figure by 17.2. Water with a hardness concentration of 200 mg/L (12 gpg) is considered undesirable and water having 500 mg/L (30 gpg) is considered unsuitable for domestic use.

The units designed for treatment of hardness are called water softeners. Only the water to be heated and cold water used for laundry and washing purposes need be softened. Flush toilets use a large amount of water and a considerable saving can be

realized by not softening this water. A tap for cold unsoftened water may be installed for drinking purposes in the kitchen.

There are two major types of softeners. The first type removes calcium and magnesium by exchanging them for sodium atoms. Water flows through an exchange resin charged with sodium. Calcium and magnesium in the water are traded for sodium. Once the resin becomes saturated with calcium and magnesium, it can be regenerated by backwashing brine. These softening units increase the sodium content of the water. Persons with heart trouble or high blood pressure should consult their doctor before drinking water softened by this method. Figure 7 illustrates a typical ion-exchange softener.

The size of unit to be used is determined by (a) the amount of water used, (b) the hardness of the water, and (c) the frequency of brine regeneration.

The cost of a unit depends upon its size. A unit treating 20 gpg (342 mg/L) hardness at an 8 gpm (30 litres/min) output costs between $700 and $800. A unit capable of treating 60 gpg (1026 mg/L) hardness at a 10 gpm (40 L/min) output costs between $1,100 and $1,400. Softeners of this type are available from most local water treatment retailers (see Appendix A for list of current retailers).

Water softeners will also reduce iron and manganese. On the negative side, adding sodium to the water (as mentioned previously) may make the water more corrosive which may lead to

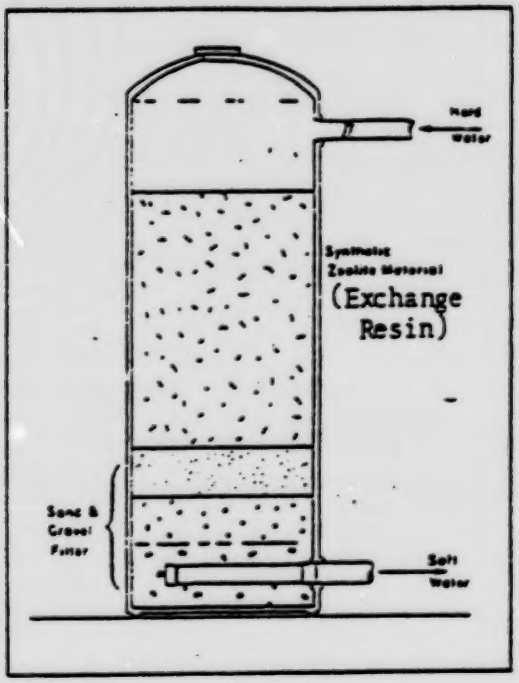

FIGURE 7. Water Softener

pipe and fixture corrosion. Water softeners alone are, therefore, not desirable for those waters which are naturally corrosive.

Operation costs for water softeners will vary with the hardness of the water, the amount of water used, and the softness desired. A unit to treat water with 150 mg/L of hardness for a family of four would take about one bag of salt per month. A bag of salt costs from $5.50 to $7. Maintenance of the equipment may be up to $50 per year depending on the quality of the equipment.

The other method of treatment is hardness-complexation with the use of phosphate additives. Chemicals such as sodium hexametaphosphate are added to the water by a chemical feeder. These chemicals prevent hard water from reacting with soap to form a scum. Scale still forms in kettles and boilers, however.

A chemical feed pump (about $1,100) similar to that used for chlorine, can be used. This is a positive displacement pump that injects chemical only when the well pump is running. Pot feeders are installed on the inlet supply line and a portion of the water is passed through a canister containing slowly dissolving phosphate crystals.

4.0 IRON

In New Brunswick, iron concentrations in groundwater can range from 0.01 to 10.0 mg/L. Iron concentrations greater than the recommended limit of 0.3 mg/L (Table 1) may stain sinks (red-yellow), discolour laundry, and impart a bitter or metallic taste to beverages (especially coffee or tea). Iron in water is not considered a health problem. The treatment systems to remove iron include conventional water softeners, followed by filtration and/or settling and chemical-oxidation filters such as greensand filters.

4.1 Water Softeners to Remove Iron

Of the treatment systems available, water softeners are the least expensive. Some models are capable of removing up to 4.0 mg/L of iron. If the water to be treated is low hardness, the use of water softeners will make the water more corrosive and reduce the concentration of beneficial elements such as calcium and magnesium.

To use a softener to effectively remove iron, the water should be clear when drawn, have a pH no less than 7.0, and be free of iron bacteria (see Table 5).

Iron in softeners can cause a problem if it oxidizes and coats the resin bed. To prevent this, the softener can be set to regenerate more frequently at a lower salt dosage to decrease the chance of iron oxidation. Alternatively, salt can be used with an additive to redissolve any iron that has oxidized.

Should the resin bed become iron-fouled, it can be cleaned with a resin cleaner such as sodium hydrosulfite ($Na_2S_2O_4$). Some of the resin cleaners available include "Iron-out", "Iron-free," and "Rover." Costs range from $8 for a 12 oz. bottle to $11 for a 16 oz. bottle. Water softeners themselves sell for between $700 and $1,400 depending on the capabilities of the unit.

TABLE 5
SELECTION OF IRON-REMOVAL METHOD *

Iron Level (mg/L)	Bacteria	Clear or Red When Drawn	pH	Method
0 - 5	No	Clear	6.5 - 7.0+	Softening
0 - 5	Yes	Clear	7.0 +	Shot-chlorination oxidizing filter
5 - 20	No	Clear	7.0 +	Oxidizing filter
5 - 20	Yes	Clear or Red	7.0 +	Shot-chlorination Continuous chlorination oxidizing filters
0 - 20	No	Red	7.0 +	Oxidizing filters
20 - 30	No	Clear	7.0 +	Continuous chlorination oxidizing filter, clarifying filter
0 - 25	No	Clear or Red	5.6 - 8.0	Oxidation by Aeration/filter

*Adapted from Lehr et al., 1980, p. 177.

4.2 Oxidation-Filtration Methods

The oxidation method involves the conversion of dissolved iron to fine iron particles which are more amenable to filtration. This conversion process is called "oxidation." Contrary to what one might think, oxidation does not necessarily involve oxygen. The oxidation of dissolved iron can be accomplished with oxygen, chlorine, chlorine dioxide, ozone, and potassium permanganate. Chlorine and potassium permanganate are used most frequently.

Oxidation-followed-by-filtration methods are usually used on water with high concentrations of iron, i.e. greater than 4.0 mg/L at pH greater than 7.0. As a rule of thumb, iron filters can be used on waters which have an alkalinity of at least two-thirds of the total dissolved solids concentration and a pH of 7 or higher. While some manufacturers claim effectiveness at a pH as low as 6.5, higher ranges promote better "rust" formation and filtration (Lehr et al., 1980).

It should be noted that the units that use oxidation-filtration have a 10 - 15 percent iron bleed (i.e. iron lost) and, if iron concentrations are high enough, a water softener will be required to remove any iron that "bleeds" through the filter.

4.2.1 Oxidation by Chlorine

Chlorine is a popular treatment because chlorine can convert dissolved iron to iron particles and can kill iron bacteria as well. The rate of chlorine feed can be varied depending on

the degree of iron problem. Quite simply, the iron is oxidized by the chlorine and the resulting oxidized iron or iron particles are subsequently removed by a filter. This method is usually accomplished by injecting chlorine into the inlet of a pressure or storage tank. The chlorine feed-pump injects chlorine only when the pump is running. A tank 10 times the size of the system flow rate (gpm or litres/min) will usually provide adequate contact time.

An additional benefit of this type of oxidation-filtration is its ability to control iron bacteria. There are several types of iron bacteria common to well water supplies. These bacteria use iron as food. The bacteria deposit this iron in "sheaths" of gelatinous matter which forms a red sludge or slime. The sludge or slime accumulates where water is allowed to stand for periods of time such as flush tanks, pressure tanks, or humidifiers. Periodic "shock" or "shot" chlorination of the well is also often used to solve this problem (Appendix C). Severe cases may require extremely high doses of chlorine and flushing of the entire system. As the bacterial growths decay and slough consumers may experience episodes of dirty water.

4.2.2 Iron Oxidation by Air

An iron removal unit has been developed that makes use of air to oxidize the dissolved iron to iron particles. The iron

particles are then removed by a filter containing an oppositely charged medium. The unit is capable of backwashing the iron out of the filter media.

The unit is effective in the pH range 5.6 to 8.0 and can remove up to 25 mg/L of iron. This is four times the capacity of a greensand filter. No chemicals are used.

The main disadvantage to the unit is that it requires a minimum flow of 23 L/M (5 gpm). This is higher than the yield of many of the wells in New Brunswick. Organic contaminants such as tannin and other humic acids will prevent the iron particles from being removed by the filter.

The iron-aeration removal unit sells for about $1,000.

4.2.3 Iron Oxidation by Potassium Permanganate

Chemical oxidation using potassium permanganate ($KMnO_4$) is an alternative to chlorine oxidation. Potassium permanganate causes the dissolved iron to form iron particles faster than chlorine. It also does not give the water the "chlorine smell" that use of chlorine does. Potassium permanganate is not as pH dependent as chlorine. The decision to use potassium permanganate or chlorine as oxidant depends upon the individual water supply and system, the set of contaminants to be removed, the cost and availability of chemicals, and the tendency of the water to develop a chlorine-type odour.

4.3 Greensand Filters

Greensand is essentially a filter and an oxidant combined. The filter (sand) has the oxidant (manganese dioxide) coated onto the grains of sand. When water containing iron (and manganese) is passed through this material, the manganese dioxide on the sand causes the iron (and manganese) to come out of the water and coat onto the greensand. After the greensand is coated with iron, it is regenerated with potassium permanganate. The pH of the incoming water must be 7.0 or greater to prevent the dissolution of the manganese dioxide.

A modification to this process is available whereby the manganese dioxide is continuously regenerated with potassium permanganate. Potassium permanganate is continuously fed to the water before entering the filter. The iron and manganese are oxidized by the potassium permanganate so that they form particles which are caught up by the filter. If too little potassium permanganate is added, the untreated iron and manganese remaining in the water coats onto the greensand; if too much potassium permanganate is added, the greensand is regenerated. Thus, uniform amounts of potassium permanganate may be added to a water containing varying concentrations of iron and manganese.

4.4 Extremely High Iron Concentrations

If the iron concentration is extremely high (greater than 5 mg/L) and must be treated (i.e. another well location cannot be found) then a combination of systems may be required

including pH adjustment. A typical system may include pH adjustment, chlorination, and filtration.

4.5 Conclusions

In New Brunswick where the iron concentration in groundwater generally does not exceed 5 mg/L, a water softener is often the most effective and least expensive treatment method. A greensand filter alone may cost between $1,000 and $1,600 at 1987 prices. Chemical-oxidation-filtration would require the purchase of a chemical feed pump and a filter(s) for approximately $2,000-$2,500 for the set. Operation of a greensand filter may cost $45 per year in potassium permanganate purchases. Treatment of extremely high iron concentrations in a domestic water supply may cost as much as $5,000. Alternative water sources should be investigated prior to making this investment. Annual maintenance costs should not be overlooked.

Iron treatment units can be purchased locally under several brand names (see yellow pages under Water Treatment and also see Appendix A). Analysis of water for iron can be made by any of the laboratories listed in Appendix B.

5.0 MANGANESE

Manganese concentrations in excess of the recommended limit of 0.05 mg/L can cause grey to black staining on porcelain and pots and pans. It is not a health hazard at the concentrations normally encountered in drinking waters. In some waters in New Brunswick, manganese concentrations in well waters may reach 4.5 mg/L and higher.

Generally, treatment methods which remove manganese also remove iron and vice versa (see Chapter 4). Water softeners can remove manganese concentrations of up to 2 mg/L. Greensand filters and oxidation-filtration can remove concentrations over 2 mg/L in a manner similar to iron removal.

Before purchasing a unit for manganese removal, an expert should be consulted to determine the most appropriate treatment method. If a water softener is used, care should be taken to prevent resin fouling (see Section 4.1). The prices of units are the same as those for iron removal units.

Manganese problems may be accompanied with a "rotten egg" hydrogen sulphide smell. Many consumers have felt that these smelly water problems are related to electric hot water heaters. Changes in the sacrificial anode in these heaters from manganese to aluminum have reduced the severity of these problems. Running the heaters hot has also helped.

Similar to iron, manganese bacteria are frequently a contributory factor. The use of disinfection should be considered.

6.0 ACID WATER

Acidity is commonly expressed in pH units (although technically speaking this is not entirely correct). The pH scale ranges from 0, which is extremely acid, to 14, which is extremely basic (caustic; alkaline). A pH of 7.0 is neutral. The average pH of groundwater in New Brunswick is 7.0. The pH values for various substances are shown on Table 6.

TABLE 6
AVERAGE pH OF VARIOUS SUBSTANCES

Substance	Average pH
Groundwater (N.B.)	7.0
Vinegar	2.4 - 3.4
Beer	4.0 - 5.0
Soft Drinks	2.0 - 4.0
Milk	6.3 - 6.6
Household Bleach	10.0
Rain Water	3.8 - 6.0

Acidic water is frequently, but not necessarily, corrosive. Some of the factors influencing corrosion include the dissolved oxygen content, carbon dioxide content, bacterial activity, the mineral content, the temperature, the catalysts present, and the pH of the water. For instance, seawater is corrosive yet is not acidic.

Low pH water may stimulate corrosion of plumbing. This corrosion is frequently indicated by elevated lead, copper, and/or zinc concentrations in the water. Treatment methods usually neutralize the pH of the water in order to better control treatment variabile.

Acid water is more common in dug wells than drilled wells. This is largely because shallow groundwater and surface water have had less opportunity for neutralization by geologic materials.

There are two types of units that deal with acid water:

1. Tank-type neutralizing filters.
2. Chemical feed pumps supplying a caustic (basic) material such as soda ash.

It should be noted that any pH adjustment of acid water may cause iron and manganese to "come out" of the water and clog the filter, well, or plumbing system. Where possible, a complete analysis should be carried out to assess this potential problem.

6.1 Tank-Type Neutralizing Filters

The tank-type neutralizing filter uses a mode of operation similar to chemical reactions which occur in nature. The filter-medium is crushed limestone, magnesia, or both. When the acid water passes through the filter, it dissolves some of the limestone present in the filter. Thus, the water is hardened somewhat through the neutralization process.

The neutralizing filters are not very effective on pH's lower than 6.0. A limestone filter, on average, will raise the pH of the water by approximately one pH unit. Magnesia filters can raise the pH higher, depending on the water composition.

The limestone bedding can cause pressure loss across the filter. Also the flow rate must often be restricted to insure adequate neutralization. In addition to this, because it makes use of a dissolving medium, it will be necessary to periodically replace the filter bed.

Tank-type units sell for approximately $1,000.

6.2 Chemical Feed Pumps

A chemical feed pump using soda ash (sodium carbonate), calcium hydroxide, or sodium hydroxide can treat water with a pH of 4.0 to 6.8. It involves a simple acid-base neutralization which requires a minimum of contact time. The alkali can often be injected directly into the well preventing any part of the plumbing system from contacting the corrosive water.

Neutralization by this method requires the handling of dangerous caustic solutions. Typically soda ash is mixed with a ratio of 1 to 2 kg (2 to 4 lb.) per 15 litres (4 gal.). It is fed at a rate sufficient to raise the pH to 7.0 at the faucet farthest from the installation. This necessitates some manual adjustments to the feed rate.

To neutralize water with pH below 4.0 sodium hydroxide is added by a chemical feed pump. It is mixed at the same concentration and injected in the same way as soda ash.

Both of these chemical feed injection methods are relatively inexpensive and easy to maintain. Maintenance involves keeping the solution tank full and adjusting the feeder by trial

and error to achieve a desirable pH of about 7.0. pH can be measured with a pH meter available at any laboratory equipment retailer or with chemical indicators which change colour with pH. Chemical indicators (i.e. litmus paper) are available from water treatment companies and tropical fish stores.

6.3 Caustic Waters

For scale forming, extremely high pH waters, sulfuric acid can be added via a chemical feeder instead of sodium hydroxide. This is another neutralization type of reaction and the same rules of operation apply as for acid water.

6.4 Sodium Silicate

In municipal systems a popular treatment for corrosion control is the use of sodium silicate. Unlike the aforementioned methods, no neutralization of acids is involved. The idea is that the silica will form a film on the piping to protect the plumbing from corrosion. The treatment must be relatively continuous, and effectiveness is (generally) improved by high water velocity and lower pH values (American Water Works Association, 1981).

Treatment systems available locally consist of simple in-line filter cartridges containing sodium silicate as well as other treatment media such as activated carbon. The manufacturers claim that these "inhibit scale buildup and corrosion." While water is sitting in the filter, sodium silicate will slowly

dissolve into the water. When the water system is used, the dissolved sodium silicate will leave the filter and presumably coat the inside of the piping.

These filters sell for approximately $110.

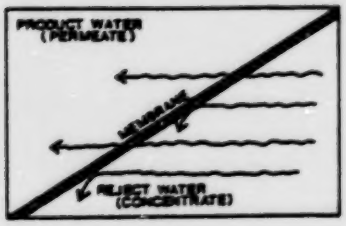

FIGURE 8. Water Treatment with an osmotic membrane.[1]

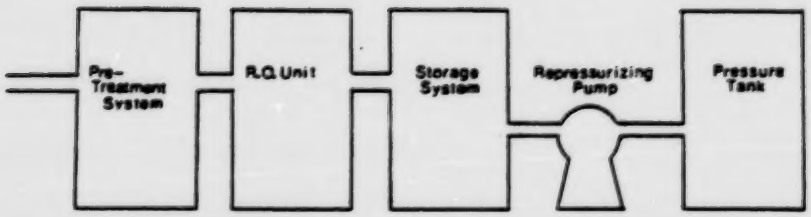

FIGURE 9. Organization of a water-supply system with a reverse osmosis unit.[2]

[1]Lehr et al., 1980, p. 184.
[2]Lehr et al., 1980, p. 185

7.0 CHLORIDE, SULPHATE, AND NITRATE

The recommended limits for chloride, sulphate, and nitrate in drinking water in Canada are 250 mg/L, 500 mg/L, and 10 mg/L (45 mg/L nitrogen), respectively. High chloride concentrations often mean high sodium concentrations, a potential concern for persons with high blood pressure or heart trouble. Chlorides are responsible for the salty taste in water. Sulphate imparts a bitter taste to the water and may cause a laxative effect to a new consumer. Nitrate is often indicative of contamination from such sources as septic fields, fertilizers, and manure piles. Levels in excess may cause methemoglobinemia or "blue baby" in infants (a condition where the red blood cells do not carry enough oxygen) whereby the child becomes listless and the skin takes on a blue hue.

There are four major types of treatment methods to remove these chemicals: reverse osmosis, dealkalization, deionization, and distillation. Distillation is discussed in Section 15.2.

7.1 Reverse Osmosis

Reverse osmosis involves passing mineralized water under pressure through a semi-permeable membrane. This membrane allows fresh water to pass through the membrane while leaving many of the minerals behind.

There are many types of reverse osmosis membranes with nylon and cellulose acetate being the most common. The membranes are highly susceptible to build-up of calcium or sulphate compounds on the membrane. Some species of bacteria may feed on the membrane requiring the use of chlorine or ozonation to kill the bacteria before they reach the unit. Then some treatment may be required to remove the chlorine or oxygen. Iron may also clog the membrane.

Generally, iron and hardness should be removed by treatment with a softener or some other method before the water reaches the reverse osmosis membrane. At the very minimum, there should be a paper dirt/rust filter before the unit and a charcoal filter after the unit.

As shown in Figure 8, water is forced against a membrane in the unit. This part of the module retains the solids and, to prevent clogging, must be constantly washed to waste by the incoming water supply. It is estimated that for every litre of water produced, four litres go to waste. An average unit produces about five gallons of water per day and fits under the sink. The efficiency of the unit with respect to the production of water is temperature dependent. At 25^{o}C reverse osmosis units are most efficient. The effectiveness of the unit in removing the minerals of concern can vary from 50 to 90 percent depending on the quality of the water being fed into the unit.

A typical reverse osmosis setup is illustrated in Figure 9. The cost of the units available in New Brunswick are

in the $800 to $900 range. The membrane ($20 - $40) is usually changed once a year. The cost of the pretreatment systems mentioned previously depends on the quality of the input water and the type of pretreatment required.

7.2 Dealkalization

A dealkalizer or anion exchange system is designed to remove the sulphates. This works on the same principle as a water softener, the sulphates are exchanged for chlorides using a modified resin. The unit, therefore, increases the total chloride concentration. If chloride is already a problem, this unit is not recommended.

7.3 Deionization

Deionization or demineralization is designed to remove all of the minerals from water. The deionization unit operates like a water softener except there are two types of resins, one to remove positively-charged minerals (cations) and another to remove negatively-charged minerals (anions). These units are relatively expensive ($2,000 - $3,000).

The use of ion exchange systems for demineralization should only be considered for treatment of water with less than 2000 mg/L TDS (total dissolved solids) concentrations. These units are quite efficient and mechanically simple to operate.

Disadvantages include maintenance such as regenerating the resins and disposal of the waste brine solutions and a resulting flat-tasting, very soft water lacking many beneficial minerals.

7.4 Nitrate Removal by Freezing/Thawing

Research by Rowe (1983) and McCurdy (personal communication, 1985) has indicated that nitrates can be separated from water by freezing the water. Unlike previous methods described, this method does not require the purchase of special treatment units. When 70 percent of water is frozen, approximately 90 percent of the nitrate is concentrated in the remaining 30 percent of liquid water. This water is then poured to waste and the ice is thawed for consumption. The result is a water that contains 90 percent less nitrate than it did originally.

8.0 HYDROGEN SULFIDE

Hydrogen sulfide gas (H_2S) is a by-product of the decay of organic matter and the weathering or sulfide deposits. It is produced when microorganisms degrade sulfur-containing materials in environments devoid of free oxygen. Commonly, hydrogen sulfide problems can be related to the growth of iron or manganese bacteria. Hydrogen sulfide problems are common in New Brunswick and are easily identified by a characteristic rotten egg odour. The problem can often be corrected by ensuring that oxygen is abundant in the well. This can be accomplished by using vents on the well which allow air to contact the water. If the problem persists, water treatment options are available. These include activated carbon filters, oxidizing filters, and oxidation-filtration.

8.1 Activated Carbon Filtration

Activated carbon or charcoal filters are effective for low levels of H_2S (less than 1 mg/L). The gas is absorbed by the carbon filter until the filter is saturated, at which time the charcoal requires replacement. The actual unit resembles an iron filter, but the filter bed cannot be backwashed or otherwise reused when it is used for H_2S removal. The carbon will absorb more than just the H_2S gas. Accordingly, the filter's life can be shortened by other less obnoxious impurities such as iron. Ordinary activated carbon filtration units may allow bacteria in

water passing through the filter to grow on the charcoal (Perry et al., 1981). Accordingly, the filters should be replaced on a regular basis.

The cost of a unit is quite variable. A small faucet-attached unit might cost $40 - $60 while a larger cartridge-type unit might cost between $200 and $300. A unit for treatment of all the water used by a home may cost $1,000 with a $200 cost for periodic bed replacement.

8.2 Oxidizing Filters

Oxidizing filters cause H_2S to form sulphates which have no odour. Potassium permanganate or chlorine added to the water with a chemical feed pump will cause oxidation to occur. A filter is usually required after the addition of the potassium permanganate or chlorine to pick up whatever other minerals (i.e. iron and manganese) that have come out of the water because of the oxidation. Frequently, a greensand filter is recommended. This unit can then correct the odour problem and also remove iron and manganese. Alternatively, chlorine addition can control iron bacteria problems while removing the H_2S.

Prices of these filters are similar to those for iron filters of similar design.

9.0 ARSENIC

Arsenic occurs naturally in many rocks, minerals, and soils. In York and Charlotte Counties of New Brunswick, there are several areas with high arsenic concentrations in the drinking water although clinical cases of chronic arsenicalism have not been identified in this area (Bottomley, 1984).

Arsenic is a cumulative toxin affecting the nervous system. The recommended limit for arsenic in drinking water in Canada is 0.05 ppm (mg/L).

Until recently, the only solution to an arsenic problem has been to find an alternate source of water. There are now several treatment units available to remove arsenic from water. One such unit was developed by the Nova Scotia Research Foundation Corporation and is being marketed by P & H Enterprises Ltd., General Contracting. The unit sells for approximately $1,500.

The operation of this arsenic unit is much the same as that of a greensand filter. Arsenic-bearing water is passed through a chlorination unit and then through a bed of ferric hydroxide which causes the arsenic to coat onto the bed. The ferric hydroxide can cause this "coating" to occur over the pH range of most groundwaters and requires a contact time of one minute.

Reductions in arsenic concentration as high as 99.9 percent have been realized. Beds 43 x 25 centimetres (19 x 10 inches) are capable of treating 360,000 litres (79,200 imperial gallons) of water containing 0.25 mg/L arsenic. It has been

shown to reduce arsenic concentration to less than 0.01 mg/L. When used at a rate of 23 litres (5 gallons) per day to supply only cooking and drinking water, these units are expected to have a theoretical life of 40 years.

An alternative treatment unit designed for the removal of arsenic from drinking water is also available. The system is comprised of two disposable activated alumina cartridges connected to a separate cold water faucet and is usually installed on the kitchen sink. The cost of the system is approximately $700. The life span of the cartridge is 1.5 to 2.0 years depending upon the concentration of arsenic to be treated, the amount of water used, and the pH. The cost of cartridge replacement is in the range of $90 to 100. Tests to date of this system indicate that reductions of arsenic from 0.13 to 0.16 mg/L to less than 0.005 mg/L have been achieved. This is a reduction of greater than 97 percent.

Reverse osmosis (RO) has also been found effective in the removal of arsenic from water supplies. Tests conducted by the Nova Scotia Department of Health indicate that RO units can reduce arsenic concentrations of up to 1.2 mg/L to below 0.005 mg/L representing a 99.6 percent removal efficiency. Reverse osmosis units by themselves sell for $800 - $900. However, pretreatment is frequently required (i.e. softening) which raises the cost of this method of treatment (Section 7.1).

Arsenic can also be removed with a distillation unit (Section 15.2).

Analysis for arsenic can be carried out at one of the chemical laboratories listed in Appendix B.

10.0 ODOUR AND TASTE

Taste and odour causing substances include: methane, hydrogen, sulfide, industrial wastes, pesticides, decaying plant and animal matter, gasoline, oil, phenols, residual chlorine, and certain by-products of chlorination. Often these materials are present at levels which are undetectable by laboratory analysis instruments but are detectable by human senses (Table 7).

The solution to the odour/taste problem depends, to some extent, on the source of the problem. For instance, gasoline and oil do not readily decompose in the ground. They can travel long distances and remain in the soil for a long period of time. The best solution for this type of problem is to remove the soils containing the gas or oil, eliminate the source, and install an activated carbon filter until the oil or gasoline can no longer be detected. Of course, an alternate water supply is also another option in this instance.

TABLE 7

ODOUR AND TASTE CHARACTERISTICS OF COMMON INORGANIC CHEMICAL CONSTITUENTS FOUND IN WATER *

Chemical	Taste or Odour Characteristics In Water
Iron	Bitter Taste Metallic Taste
Manganese	Bitter Taste
Sulfate	Bitter Taste
Hydrogen Sulfide	Rotten-egg Odour
Sodium Chloride	Salty Taste
Bicarbonates	Flat, Soda Taste
High TDS Content	Salty Taste

* Lehr et al., 1980, p. 111

10.1 Activated Carbon Filters

Activated carbon or charcoal filters can remove low concentrations of taste and odour from a wide variety of sources. The activated carbon "absorbs" the offending chemicals onto its surface (see also Section 8.1).

There are two major types of activated carbon filters; cartridge type and bed type. Cartridge types are easily installed directly on a faucet. Once they have used up their filtering capacity, the entire cartridge is replaced. There are also larger, under-the-sink cartridges available which can be backwashed to remove heavier solids build-up (Figure 10).

Bed-type carbon filters are designed to treat most of the water being used in a home. This type of unit is usually placed beyond the chlorinator and/or the water softener. The unit can be backwashed periodically to remove suspended dirt. The frequency of backwash depends upon the rate of use and the manufacturer. For an average household, an activated carbon unit will last 1 to 3 years depending on quantity of water processed and the intensity of taste and odour (Figure 11).

Some of the less sophisticated activated carbon filtration units may allow bacteria in water passing through the filter to attach themselves to the charcoal. The moist dark environment and the organic food supply may allow these bacteria to grow on the charcoal (Perry et al., 1981). Therefore, in the use of ordinary charcoal filters, it is necessary to change to filters on a regular basis to minimize bacterial growth.

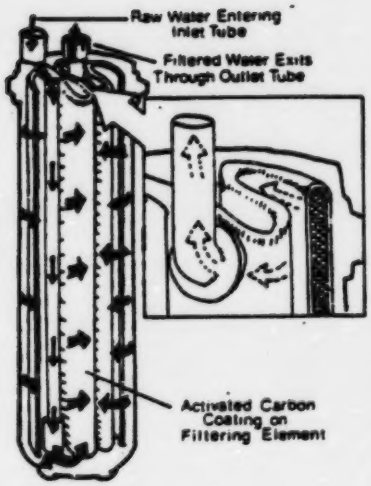
Raw Water Entering Inlet Tube
Filtered Water Exits Through Outlet Tube
Activated Carbon Coating on Filtering Element

Figure 10

One model of cartridge-type activated-carbon filter. Water is filtered as it passes from the outside of the filter element into the inner area. The inset shows how filtered water inside the element is collected and discharged through a special outlet. (*From American Assoc. for Materials, 1973.* "Planning for an Individual Water System.")

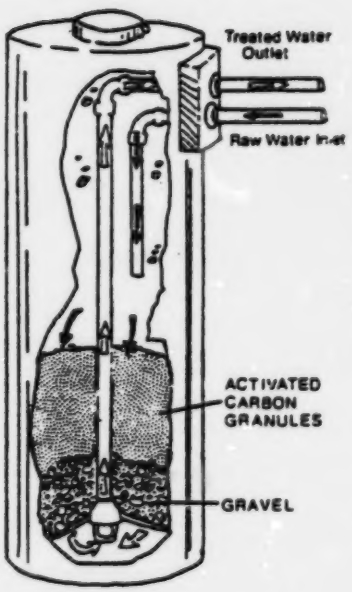

Figure 11

Activated-carbon-bed-type filter in the service mode of operation. Water flows through the control valve, down through the activated-carbon bed. The activated carbon will adsorb chlorine and other taste- and odor-producing organic matter until its capacity is exhausted. The filtered water then flows up through the distributor system, back through the valve, and to the water-supply system. Black arrow indicates unfiltered water. White arrow indicates filtered water. (*F. E. Myers and Bros., Co.*)

*Lehr et al., 1980, p. 114

10.2 Oxidation Chlorination

Chlorination is somewhat effective in the elimination of odours because it changes some chemicals that cause odours and it eliminates bacteria. Oxidizing agents such as chlorine, potassium permanganate, and ozone cause offending substances to form particles after which they can be filtered out.

Use of chlorination prior to carbon filtration to remove odour and taste caused by phenols may cause potentially toxic compounds to be released by the activated carbon treatment (Voudrais et al., 1985).

10.3 Aeration

Aeration removes tastes and odours when the responsible agent is a gas such as hydrogen sulfide or methane. This technique involves exposing the water to air by means of turbulence or "bubbling" of the water. Well water hydrogen sulfide odour may be eliminated by ensuring the well vent is clear, allowing oxygen to access the water.

Units designed to remove odour and taste are available locally. Small activated charcoal units are available at any of the firms listed in Appendix A. They are also available in many hardware and department stores.

11.0 CLOUDY WATER

Turbid or cloudy water is caused by the suspension of particles in the water. The Canadian Drinking Water Guidelines (Table 1) have set five nephelometric turbidity units (NTU) as the maximum acceptable level with an objective level of less than one NTU. This limit has been established on the basis of both health and aesthetic considerations. Turbidity in excess of 5 NTU may result in a noticeable cloudiness in the water and, consequently, may be considered objectionable. High levels of turbidity can also protect micro-organisms from the effects of disinfection and stimulate the growth of bacteria.

Turbidity is a common problem in surface water supplies where erosion affects a watercourse, in dug wells receiving water from the surface, and in drilled wells constructed in soft bedrock. A leaky well casing may also cause this problem.

There are three major methods for alleviating a turbidity problem: coagulation, sedimentation, and filtration.

11.1 Coagulation

Coagulation is a process by which fine suspended particles collect into large particles that settle to the bottom. The process is started by adding to the water a chemical such as alum which causes suspended particles to combine and form larger particles. Factors affecting the coagulation rate include pH, water temperature, particle size, rate of water coagulant mixing, and the ultimate quantity of coagulant used.

Other coagulants include ferric chloride and ferric sulfate. When the pH ranges between 6.8 and 7.5 alum is recommended. If the pH is 5.5 to 8.8, ferric sulfate can be used.

11.2 Sedimentation

Sedimentation involves letting the water stand still while gravity causes the larger particles to settle out. For a significant reduction in suspended matter, the detention time must be at least 24 hours.

The inlet to the sedimentation tank should be designed so the incoming water is distributed across the entire width of the tank. The outlet should be located at the opposite end of the tank. Baffles should be used to reduce short circuiting of water and thereby reduce high local velocities. The system should be designed with two separate sections to facilitate cleaning and repair. The frequency of cleaning will depend on the size of the tank, the turbidity, and the water usage rate.

11.3 Filtration

Filtration is the process of removing suspended matter from water as it passes through beds of porous material. Filters filled with sand or diatomaceous earth can be purchased as cartridges which can be added to water lines.

Details on the above methods can be obtained from the dealers listed in Appendix A. Prices vary with sedimentation being the least expensive and filtration being the most expensive.

12.0 URANIUM

Uranium is widely distributed and is present in a variety of minerals. In New Brusnwick, uranium has been noted to occur in groundwater associated with Missippian volcanic rocks in areas of York and Charlotte Counties (personal communication, L. Peters, Chief - Groundwater Section, New Brunswick Department of Municipal Affairs and Environment, 1986).

In Nova Scotia, uranium has been found in drilled wells which penetrate thick deposits of glacial overburden in granite areas. At present, the only solutions to excessive uranium in water are construction of a replacement dug well, installation of a distillation system (Section 14.3), or obtaining water from other sources. It has been noted that in some cases, water softeners will reduce the uranium concentration by a small amount. Reverse osmosis systems may also be effective in uranium removal.

In natural waters, the type of uranium of concern is the uranyl ion. Uranyl salts dissolve easily in water and produce an objectionable taste and colour when they exceed a concentration of 5 mg/L as uranium. At considerably higher levels, ingestion of water containing uranyl ions may result in possible kidney damage. The recommended drinking water limit is 0.02 mg/L uranium. This limit is based on the chemical properties of the uranyl ion rather than on radioactivity.

Radon gas, the daughter product of uranium decay, may also be a problem in some wells. This heavy gas is slightly radioactive and may become hazardous if allowed to accumulate in

unventilated areas typically basements and bathrooms. The use of aerators on faucets and adequate ventilation of bathrooms and basements are the best precautions against radon gas build-up. Wells should be drilled out of doors and should have the well casing extend to the surface of the ground (pitless adaptor construction) where any gas build-up can be easily vented.

13.0 HYDROCARBONS AND OTHER ORGANIC CHEMICALS

With increasing frequency, wells are becoming contaminated with such manmade chemicals as gasoline, fuel oil, perchlorethylene (PCE, drycleaning solvent), phenols (from creosote), or trichlorethylene (TCE, degreasing agent). Where the well is contaminated with any manmade chemical, the initial idea is to remove the source of the contamination. The treatment methods described in the following sections should be regarded as temporary. Many of the methods are new and have not been fully tested over the full range of petroleum products.

13.1 Hydrocarbons

The term hydrocarbons as stated here includes fuels such as gasoline, diesel fuel, or stove oil. In almost every instance, homeowners notice the presence of these chemicals in their water by the strong odour, particularly in hot water. The nose can detect gasoline down to concentrations of 0.5 parts per billion (ppb) and fuel oil down to 1.0 ppb.

Generally, any concentration of hydrocarbon makes the water unacceptable for drinking. Constituents of fuels such as xylene, toluene, and benzene have been associated with cancer. Sampling for hydrocarbons requires special glass bottles available through the Department of Health or the Department of Municipal Affairs and Environment.

13.2 Phenols

The main sources of phenols in well water are creosote used for wood preservation and gasoline. Phenols have a strong taste and odour. The maximum acceptable concentration for phenols is 0.002 mg/L (2 ppb) and is based on aesthetic considerations.

13.3 Perchlorethylene and Trichloroethylene

Both perchloroethylene (PCE, tetrachloroethylene) and trichloroethylene (TCE) are organic solvents. They are designed to dissolve fats and greases. PCE is most frequently used for drycleaning but is also present in some household degreasers. Trichloroethylene is primarily used for degreasing by industry.

At the relatively low concentrations which occur in well waters PCE and TCE are not detectable by odour or taste. The suggested World Health Organization drinking water limits for PCE and TCE are 10 and 30 ppb (parts per billion), respectively. PCE and TCE have been associated with liver cancer among laboratory animals consuming large quantities of the chemicals.

13.4 Treatment

The following methods have been suggested for the removal of the above-mentioned chemicals although their effectiveness has not been fully tested.

13.4.1 Granular Activated Carbon

Granular activated carbon (GAC) or charcoal filters have proven to be effective in removing low levels of hydrocarbons and other organic chemicals. The life of the bed will depend on the concentration of the contaminant present and the amount of water used. The results of studies by the University of Maine on the life of GAC units are shown on Table 8 (Lowry and Lowry, 1985). As an example, the study found that running 744 Imperial gallons of water contaminated with 15.0 mg/L of gasoline through a 1.2 cubic foot activated-carbon bed resulted in the saturation of the carbon bed within 7 days. Obviously, the use of such a bed would not be cost-effective in this situation. Often several GAC units are added in sequence to minimize the frequency of bed replacement on a single filter unit.

As mentioned in Section 10.1, some of the less sophisticated GAC filtration units may allow bacteria to act on the activated carbon (Perry et al., 1981). Use of chlorination prior to GAC filtration is not recommended because potentially toxic compounds may be released by the activated carbon treatment (Voudrais et al., 1985).

Sometimes pretreatment for iron and manganese removal is required in the case of gasoline contamination. Gasoline may cause these minerals to "dissolve" out of soil or bedrock. Household sized GAC units cost $1,000. A typical bed replacement cost is $200.

TABLE 8

Bed Life Estimates for
Granulated Activated Carbon Treatment Units
(Imperial Measurements)

Bed Size	Gasoline Influent Concentration[1]			
	1.0 mg/L		15.0 mg/L	
	days	Imp. gallons	days	Imp. gallons
1.2 cu. ft.	20	2,128	7	744
1.8 cu. ft.	20	2,128	7	744
2.5 cu. ft.	90	9,600	10	1,064

Bed Life Estimates for
Granulated Activated Carbon Treatment Units
(Metric Measurements)

Bed Size	Gasoline Influent Concentration[1]			
	1.0 mg/L		15.0 mg/L	
	days	Litres	days	Litres
0.034 cu. metres	20	9,674	7	3,382
0.051 cu. metres	20	9,674	7	3,382
0.071 cu. metres	90	43,641	10	4,837

[1]20 ppb breakthrough criteria.

13.4.2 Reverse Osmosis

Reverse osmosis (RO) units are apparently capable of removing the aforementioned chemicals. RO units are available to treat the entire household water supplies. According to Lowry and Lowry (1985), some of the problems associated with RO units is that they use a water volume of at least four times the normal supply and produce waste water that has a higher contamination level than the raw water. Therefore, there is a possibility of contaminating your well via your domestic septic system, as well

as the original source of the contaminant. RO units would not require the periodic bed replacement that is required by granular activated carbon units.

13.4.3 Aeration

Lowry and Lowry (1985) have developed an aeration system for removal of volatile organic chemicals such as those described. The system consists of a series of vessels in which air is pumped into the water. The water passes from vessel to vessel until all of the contaminant has been driven off. The contaminant is vented to the air, a possible problem with some explosive or odourous contaminants. The system is capable of treating water containing several hundred mg/L of gasoline.

The Lowry's treatment system has several advantages over the granular activated carbon system, the most important of which is the lower operating cost. There is no activated carbon bed to replace. They estimate the installation cost to be $2,500 (US) to $2,800 (US). The system is most cost effective in highly contaminated water systems, i.e. several hundred mg/L of gasoline.

14.0 COLOUR

Most frequently colour in groundwater is caused by the presence of iron and/or manganese. Accordingly, the colour problem is dealt with by the removal of the iron and/or manganese.

However, some colour is not caused by the presence of iron and manganese. It may be caused by the presence of humic acids. Humic acids are the result of the breakdown of leaves and plants into a black humus soil. These are leached out as water percolates through these soils. Usually the deeper soils will filter out the humic acids. However, in areas where there is little soil or it is boggy, or where the well is improperly cased into bedrock, humic acid-containing waters may enter wells. Humic acids give the water a clear brown colour similar to weak tea. Generally, they are not known to be harmful. However, chlorination of water containing humic acids may form cancer-causing materials (Meier et al., 1984). Also, use of chlorination prior to carbon filtration to remove humic acids may cause potentially toxic compounds to be released by the activated carbon treatment (Voudrais et al., 1985).

Humic acids can be removed by charcoal filters (Section 10.1), by ozonation (Section 2.2), or by means of coagulants (Section 11.1).

15.0 SODIUM

Of late, the sodium concentration in drinking water has become a concern for many people. Yet, the intake of sodium from drinking water is only a small portion of that consumed in food. For instance, it is estimated that milk contains 520 mg/L of sodium (US Department of Agriculture). Tomato soup contains 3,900 mg/L of sodium.

The suggested drinking water limit for persons on salt-restricted diets is 20 mg/L sodium. Excessive amounts of sodium in diets has been related to the development of high blood pressure and hypertension (National Academy of Sciences, 1977).

One source of sodium that seems to be of public concern is water softeners. Water softeners will add sodium to drinking water. The amount of sodium added is related to the hardness of the water, i.e. the harder the water, the more sodium added by the softener.

Sodium can be removed from drinking water by means of reverse osmosis units or distillation units.

15.1 Reverse Osmosis

Due to the small size of the sodium atom, reverse osmosis (RO) units are not 100 percent effective in the removal of sodium from drinking water. The effectiveness of the unit ranges from 60 to 95 percent. The effectiveness of the unit is dependent on the type of membrane and the quality of the water. RO units are discussed in Section 7.1.

15.2 Distillation

Distillation is another option available for the removal of sodium and many other minerals from drinking water. These units operate by boiling the water, gathering the resulting steam, and cooling and condensing it to liquid water again. Bacteria are destroyed by the heat and minerals are left behind in the boiler. The process results in nearly pure water.

Distillation's main advantage is its simplicity of operation. No pretreatment is required. The units produce approximately 27 litres (six gallons) of drinking water per day. Essentially all the minerals in the water are removed, making the unit suitable for treatment for practically any water quality problem. A study of the system by the Nova Scotia Department of Health (Don Feldman, personal communication, 1985) revealed that buildup of minerals in the boiler was not a problem due to the low concentration of minerals in the water. The main disadvantages to distillation are the power consumption and noise the unit can make. The unit tested by the Nova Scotia Department of Health was a 1000 watt unit that the homeowners kept in the basement because of its refrigerator-type noise. It sold for approximately $1,000.

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APPENDIX A

A PARTIAL LIST OF FIRMS DEALING WITH DOMESTIC WATER TREATMENT

PARTIAL LIST OF FIRMS DEALING WITH DOMESTIC WATER TREATMENT

Company	Equipment Brand Carried
Connell's Plumbing and Heating Ltd. 616 Main Street P.O. Box 1389 Woodstock, New Brunswick 328-2074	Purifiner
Culligan Moncton 140 King George Highway Newcastle, New Brunswick 853-5050	Culligan
Culligan Water Conditioning 181 Westmoreland Box 355 Fredericton, New Brunswick 458-5670	Culligan
Culligan Water Conditioning Darlings Island Hampton, New Brunswick 1-800-222-8501	Culligan
Darling Duro Limited 163 Glenwood Drive Moncton, New Brunswick 458-8050	Duro
Harold Edmonson Plumbing & Heating Ltd. 278 Main Street Fredericton, New Brunswick 472-4265	Duro
Emmerson Service Centre 91 Russell Street Saint John, New Brunswick 658-0000	Water Refining
Fraser Home Services North Nappan Road Newcastle, New Brunswick 773-3505	Miracle Water
Le Groupe Opus Sante 577 Victoria Street Edmunston Mall Edmunston, New Brunswick 735-5513	Erie

James E. Lawton Plumbing and Heating 845 Old Black River Road R.R. #2, Box 6 Saint John, New Brunswick 633-0118	Duro
Lindsay Soft Water Box 4, Site 10 Upper Aboujagane, New Brunswick 532-3016	Lindsay
Oromocto Plumbing and Heating Ltd. 292 Restigouche Road Oromocto, New Brunswick 357-3741	Duro
Smith Seldon & Sons Ltd. No. 1 Highway St. Stephen, New Brunswick 466-1903	Duro
Taylor's Plumbing and Heating Ltd. 278 Millar Avenue Newcastle, New Brunswick 622-3557	
Doug White Plumbing and Heating The Water Purifiner 496 New Maryland Road Fredericton, New Brunswick 459-8360	Water Refining - Miracle Water

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This list has been compiled for public information and assistance only. The New Brunswick Department of Municipal Affairs and Environment has not evaluated a particular firm's qualifications and services. It is the responsibility of the client to make his/her own evaluation and selection.

APPENDIX B

Laboratory Facilities

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Laboratory Facilities

Atlantic Analytical, 27 Clyde Street, Saint John, New Brunswick E2L 5A8. Telephone: (506) 634-1771. Minimum Charge: $75/sample.

Environmental Chemistry, Division of Clinical Chemistry, 5788 University Avenue, Halifax, Nova Scotia. Telephone: (902) 428-3466

K-F Laboratories, P.O. Box 1390, Fredericton, New Brunswick E3B 5E3. Telephone: (506) 455-0612

RPC, P.O. Box 6000, Fredericton, New Brunswick E3B 5H1 Telephone: (506) 452-8994. Minimum Charge: $125/sample.

Bacterial sample bottles can be collected from the District Medical Health Office. The water sample should be returned to the Health Office as soon as possible after collection. Bacterial analysis is free in New Brunswick.

NOTE: Where well pollution problems are suspected, New Brunswick Department of Municipal Affairs and Environment inspectors should be contacted prior to having the water analyzed. Inspectors can be found at the following addresses:

Moncton: P.O. Box 5001, 774 Main St. E1C 8R3
Telephone: 858-2588
Chatham: Provincial Building, 337 Water St. E1N 1B2
Telephone: 773-6032
Bathurst: P.O. Box 5001, E2A 3Z9 Telephone: 546-2360
Grand Falls: P.O. Box 5001 E0J 1M0
Telephone: 473-5268
Saint John: 12th Floor, Suite 1232, City Hall
Telephone: 658-2258
Fredericton: 2nd Floor, 264 Argyle Street, E3B 5H1
Telephone: 453-2861

APPENDIX C

Disinfecting the Water Supply

APPENDIX C
Disinfecting the Water Supply

Chemical disinfection or chlorination is essential for new or repaired wells, cisterns, springs, pumps, and pipes. Bacteria is introduced during the construction or repair. Disinfection is the final step after all defects in location and construction have been corrected and before samples are collected for bacterial examination. Improperly located and constructed water supplies are never safe even though disinfected as outlined below. Disinfection cannot be relied on for one hundred percent destruction of harmful bacteria.

What to Use

Dry Material:	a)	Chloride of lime. About 35 percent available chlorine.
	b)	High test calcium hypochlorite (B.K.-H.T.H.-Perchloron) 50 - 70 percent available chlorine. Regular calcium hypochlorite has 25 percent available chlorine.
Sodium:	c)	Sodium hypochlorites. Usually available as a laundry bleach in grocery stores. It has many trade names. Labels will show 3 percent available chlorine.

How Much to Use

Make a 20 litre or 5-gallon batch of stock solution for water treatment as follows:

a) Chloride of lime - 780 grams in 20 litres of water (2 lbs. in 5 gallons).
b) High test hypochlorite - 390 grams in 20 litres of water (1 lb in 5 gallons) for 70 percent available chlorine and 540 g in 20 litres water (1 lb. 6 oz. in five gallons) for 50 percent available chlorine.
c) 3 percent laundry bleach - 7 litres in 13 litres of water (two gallons in three gallons of water).
d) 5 percent laundry bleach - 4 litres in 16 litres of water (one gallon in four gallons of water).

Mix solution thoroughly.

The above stock solution is about 12,500 parts per million or 1.2 percent by weight chlorine. To obtain an applied concentration of 50 ppm four litres or one gallon of stock solution should be used to treat 1,000 litres or 250 gallons of water.

To summarize and clarify the discussion on how much bleach or javex to use on your well:

1. Measure the depth of water in your well and calculate the volume of water present using the following table.

2. Add one litre of liquid laundry bleach or javex for every 60 gallons of water in the well... 1 litre bleach/60 gallons of water or 1 litre bleach/275 litres of water.

Number of litres of water per metre of water in the well:

Well Diameter (cm)	L/m	Well Diameter (cm)	L/m	Well Diameter (cm)	L/m
10	78.5	35	961.6	70	3,846.5
15	176.6	40	1,256.0	75	4,415.6
20	314.0	45	1,589.6	90	6,358.5
25	490.6	50	1,962.5	120	11,304.0
30	706.5	60	2,826.0	150	17,662.5

Number of Imperial Gallons of water per foot of water in the well:

Well Diameter (in)	Gal/ft.*	Well Diameter (in)	Gal/ft.*	Well Diameter (in)	Gal/ft.*
4	0.54	15	7.65	27	24.77
6	1.22	16	8.70	30	30.59
8	2.17	18	11.01	36	44.05
10	3.40	20	13.59	42	59.95
12	4.90	22	16.45	48	78.30
14	6.66	24	19.58	60	124.02

*To convert to US Gallons, divide by .833.

Procedure to Follow:

After your well has been tested for yield by blowing or bailing and the water is clear and free of turbidity:

1. Pour one-half the batch into the drilled well between the drop pipe and the outer casing, or directly into the dug well, cistern or reservoir. The solution may be poured or siphoned through the air vent pipe.

2. Start pump and open all taps until water from each tap has distinct odour. Stop pump and add remainder of batch.

3. Allow to stand from 12 to 24 hours.

4. Pump the supply to waste until odour of chlorine disappears.

5. The water should be tested for bacteria prior to its use (Appendix B).

If possible, take additional check samples after two weeks. Remember, disinfection of an improperly located or constructed supply will not insure its safety.